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Vertical technology transfer and the implications of patent protection

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Abstract: Significant amount of vertical technology transfer occurs between developed and developing country firms, yet the literature on intellectual property rights did not pay much attention to this aspect. We show that whether or not the incumbent and the entrant final goods producers are from the same developed country, patent protection in the developing country raises developed-country welfare if (i) patent protection in the developing country deters entry in the final goods market, (ii) the marginal cost difference between the incumbent and the entrant final goods producers is sufficiently small, and (iii) the marginal cost difference between the incumbent and the entrant developing-country firms is sufficiently high.

Key Words: Entry deterrence; Patent; Vertical technology transfer; Welfare

JEL Classification: F12; F23; L13; O34

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Vertical technology transfer and the implications of patent protection

1. Introduction

Under the current WTO (World Trade Organization) regime, an important issue is the standardization (and strengthening) of patent systems across countries, and it has gathered momentum due to the Dunkel proposal in connection with Trade Related Intellectual Property Rights (TRIPS). An important aspect of this standardization process is to strengthen patent protection in the developing countries.

The quest for finding out the effects of patent protection in the developing countries on the innovation of the developed countries and social welfare has created a vast theoretical literature in recent decades (Chin and Grossman, 1990, Segerstrom *et al*., 1990, Diwan and Rodrik, 1991, Grossman and Helpman, 1991, Deardorff, 1992, Taylor, 1994, Vishwasrao, 1994, Fosfuri, 2000, Markusen, 2001, Glass and Saggi, 2002 and Sinha, 2006). Surprisingly, the existing literature did not pay much attention to the vertical relationship between the developed and developing country firms, while this relationship is very common in today's world.

The tremendous growth of international outsourcing, which helps the developed-country firms to buy part or all of the outputs from the developing countries, certainly creates the need for considering vertical relationships between the firms. A large body of empirical evidence shows that vertical knowledge transfer occurs as firms from industrialized countries have bought outputs of firms from Asian newly industrialized countries (Hobday, 1995). As mentioned in Pack and Saggi (2001), Radio Shack and Texas Instruments have commissioned firms from newly industrialized countries to produce components or entire products, which have been sold under the name of the retailers. The results of extensive interviews in Korea in

the late 1970s show that almost half of the firms in the sample benefitted from the technical information provided by the foreign buyers (Rhee et al., 1984). Keesing (1982) found that, in Korea and Taiwan in the late 1970s, importers maintained a very large staffs based in the countries, which spent considerable time with their local manufacturers. Hou and Gee (1993) also confirm significant technology transfer by developed country importers to the producers from newly industrialized countries. The evidences on vertical technology transfer can also be found in Javorcik (2004) and Blalock and Gertler (2008).

Given the widespread phenomenon of vertical technology transfers between developed and developing country firms, we show how patent protection in the developing country affects developed-country welfare in the presence of vertical technology transfer, through its impact on market structure. To the best of our knowledge, this is the first paper which analyzes the effects of patent protection in the presence of vertical technology transfer.[1] Under vertical technology transfer, a developed country firm transfers its technology to a developing country firm, which produces the product for the developed country firm. However, vertical technology transfer may create competition in the developing country by creating knowledge spillover, which, in turn, may create entry in the final goods market. We show that whether or not the incumbent and the entrant final goods producers are from the same country, patent protection in the developing country raises developed-country welfare if (i) patent protection in the developing country deters entry in the final goods

[1] Pack and Saggi (2001) show the implications of vertical technology transfer on the profitability of developed-country firms. However, they neither consider endogenous entry in the final goods market nor consider welfare implications of patent protection in the developing country. Even if they consider both monopoly and duopoly product-market structure, entry decision in the product market is not endogenous in their analysis. Goh (2005) extends Pack and Saggi (2001) to endogenize technological effort of the developing firm, which is receiving the technology from the developed country firm. Lin and Saggi (2007) show how contractual relationship between a multinational and a local firm affects backward linkages between the firms and welfare in the local industry.

market, (ii) the marginal cost difference between the incumbent and the entrant final goods producers is sufficiently small, and (iii) the marginal cost difference between the incumbent and the entrant developing-country firms is sufficiently high. We also show that patent protection in the developing country may increase or reduce the profit of the developed-country firm.

It is now worth relating our result with an earlier work by Klemperer (1988), which shows that entry in a Cournot oligopoly reduces welfare if the marginal cost of the entrant final goods producer is sufficiently higher than the marginal cost of the incumbent final goods producer. However, he does not consider a vertical structure. In contrast, in a vertical structure, we show that entry, which is due to knowledge spillover under no patent protection, reduces welfare (or patent protection increase welfare) if the marginal costs of the incumbent and the entrant final goods producers are close enough. Even if both Klemperer (1988) and our paper show that entry can reduce welfare, the industrial structures under which entry reduces welfare differ between these papers. Hence, whether an economy will design policies to restrict entry depends not only on the cost asymmetries between the firms but also on factors such as vertical technology transfer under international outsourcing.

The remainder of the paper is organized as follows. Section 2 describes the model and shows the results. Section 3 concludes.

2. The model and the results

We adopt the model from Pack and Saggi (2001). Assume that there is a firm, called firm 1, in a developed country, called country 1. Firm 1 has a technology to produce a particular product, which has a demand in country 1. The profit firm 1 can earn by producing in country 1 is normalized to zero. We assume that firm 1 transfers its

technology to firm 2, which is a producer in a developing country, called country 2. Firm 2 can produce the output at the marginal cost c_1, which is assumed to be zero for simplicity. However, technology transfer to firm 2 may create knowledge spillover in country 2, which allows firm 3 to compete with firm 2 at the constant marginal cost $c \geq 0$.[2] Hence, $c > 0$ captures the idea that knowledge spillover in country 2 can be imperfect. Though firm 1 could lose control over its technology, we assume that firms 2 and 3 do not have enough marketing skills to sell the product in the final goods market. As a result, firm 1 does not face any threat of competition in the product-market from firms 2 and 3.

Assume that there is a potential entrant in the final goods market, call firm 4, who cannot produce the product, yet can compete with firm 1 by purchasing the product from firms 2 and 3. We assume that either firm 4 modifies the product slightly or firms 2 and 3 modify the production process slightly for firm 4, thus avoiding the patent laws in country 1. To show our results in the simplest way, we assume that the consumers view the products of firms 1 and 4 as perfect substitutes, but the constant marginal cost of firm 4 is $d \geq 0$. This cost difference between firms 1 and 4 may capture the costs involved in non-infringing imitation. Further, if firm 4 wants to enter the market, it needs to incur a fixed entry cost, E. In the following analysis, we will consider two situations: (1) where firm 4 is from country 1, (2) where firm 4 is not from country 1.

We consider the following game. At stage 1, firm 1 transfers its technology to firm 2. At stage 2, firm 4 decides whether to enter the market or not. At stage 3, firm 2 chooses its output if there is patent protection in country 2, and the outputs are sold at the per-unit price w to firm 1 in the case of no entry by firm 4, and to firms 1 and 4

[2] It is implicit in our analysis that the cost of extra technology transfer prevents firm 1 to transfer its

in the case of entry by firm 4. If there is no patent protection in country 2, thus creating knowledge spillover in country 2, at stage 2, both firms 2 and 3 produce the outputs like Cournot duopolists, and the outputs are sold at the per-unit price w to either firm 1 or to firms 1 and 4 depending on entry of firm 4. At stage 4, firm 1 determines its output and the profits are realized if firm 4 does not enter. If firm 4 enters, firms 1 and 4 determine the outputs like Cournot duopolists. We solve the game through backward induction.

Assume that the inverse market demand function in country 1 is

$$P = 1 - q, \tag{1}$$

where P is price and q is the total output.

2.1. Patent protection in country 2

Let us first consider the situation with patent protection in country 2, thus creating no knowledge spillover in country 2. In this situation, only firm 2 produces in country 2.

If firm 4 does not enter, firm 1 chooses its output to maximize the following expression:

$$\underset{q_1}{Max}(1 - q_1 - w)q_1. \tag{2}$$

The equilibrium output of firm 1 is

$$q_1^* = \frac{1-w}{2}. \tag{3}$$

The second order condition for maximization is satisfied. Equation (3) creates the inverse derived demand curve $w = 1 - 2q_I$ for firm 2.

Firm 2 produces its output by maximizing the following expression:

$$\underset{q_{I2}}{Max}(1 - 2q_{I2})q_{I2}. \tag{4}$$

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technology to more than one firm in country 2. This is in line with Pack and Saggi (2001).

The equilibrium output of firm 2 is

$$q_{I2}^{*} = \frac{1}{4}. \tag{5}$$

The second order condition for maximization is satisfied.

The price paid by firm 1 is $w^{*} = \frac{1}{2}$. The equilibrium profit of firm 1 is

$$\pi_1^{*} = \frac{(1-w^{*})^2}{4} = \frac{1}{16}. \tag{6}$$

Welfare of country 1, which is the sum of the total profit of the firms in country 1 and consumer surplus, is

$$W_1 = \frac{1}{16} + \frac{1}{32} = \frac{3}{32}. \tag{7}$$

Let us now consider the case where firm 4 enters the market. In this situation, firms 1 and 4 maximize the following expressions respectively to determine their outputs:

$$\underset{q_1}{Max}(1 - q_1 - q_4 - w)q_1 \tag{8}$$

$$\underset{q_4}{Max}(1 - q_1 - q_4 - d - w)q_4. \tag{9}$$

Since the entry cost is sunk at the output choice stage, it does not enter into the optimization problem (9).

The equilibrium outputs of firms 1 and 4 can be found as

$$q_1^{*} = \frac{1 - w + d}{3} \qquad \text{and} \qquad q_4^{*} = \frac{1 - w - 2d}{3}. \tag{10}$$

The second order condition for maximization is satisfied. The equilibrium outputs of firms 1 and 4 in (10) give the inverse derived demand curve $w = \frac{2 - d - 3q_I}{2}$ for firm 2.

Firm 2 maximizes the following expression to determine its output:

$$\underset{q_{I2}}{Max}(\frac{2-d-3q_{I2}}{2})q_{I2}. \tag{11}$$

The equilibrium output of firm 2 is

$$q_{I2}^{*}=\frac{2-d}{6}. \tag{12}$$

The second order condition for maximization is satisfied.

The price paid by firms 1 and 4 is $w^{*}=\frac{2-d}{4}$. The equilibrium outputs of firms 1 and 4 are respectively

$$q_1^{*}=\frac{1-w^{*}+d}{3}=\frac{2+5d}{12} \quad \text{and} \quad q_4^{*}=\frac{1-w^{*}-2d}{3}=\frac{2-7d}{12}. \tag{13}$$

We assume that

$$d<\frac{2}{7}, \tag{14}$$

which ensures that, upon entry, the outputs of both firms 1 and 4 are positive.

The net equilibrium profits of firms 1 and 4 are respectively

$$\pi_1^{*}=\frac{(2+5d)^2}{144} \quad \text{and} \quad \pi_4^{*}=\frac{(2-7d)^2}{144}-E. \tag{15}$$

It is immediate from (15) that, if there is patent protection in country 2, entry occurs in county 1 if

$$\pi_4^{*}>0 \Rightarrow \frac{(2-7d)^2}{144}>E. \tag{16}$$

Under entry of firm 4, welfare of country 1 is

$$W_1=\frac{(2+5d)^2+(2-7d)^2+2(2-d)^2}{144}-E, \tag{17a}$$

if firm 4 is from country 1, but it is

$$W_1=\frac{(2+5d)^2+2(2-d)^2}{144}, \tag{17b}$$

if firm 4 is not from country 1.

2.2. No patent protection in country 2

Now consider the situation with no patent protection in country 2. No patent protection in country 2 creates knowledge spillover and may induce firm 3 to enter the market in country 2. Since we are not interested in welfare of country 2, and want entry in country 2 whenever it is allowed by the patent law, we assume away any cost of entry for firm 3. Hence, under no patent protection in country 2, firm 3 always enters both firms 2 and 3 produce in country 2.

If firm 4 does not enter and firm 1 produces like monopolist in the final goods market, the inverse derived demand curve faced by firms 2 and 3 is given by (3), which is $w = 1 - 2q_I$.

Firms 2 and 3 produce their outputs to maximize the following expressions respectively:

$$\underset{q_{I2}}{Max}(1 - 2q_{I2} - 2q_{I3})q_{I2} \tag{18}$$

$$\underset{q_{I3}}{Max}(1 - 2q_{I2} - 2q_{I3} - c)q_{I3}. \tag{19}$$

The equilibrium outputs of firms 2 and 3 are

$$q_{I2}^* = \frac{1+c}{6} \quad \text{and} \quad q_{I3}^* = \frac{1-2c}{6}. \tag{20}$$

The second order conditions for maximization are satisfied. We assume that $c < \frac{1}{2}$, which ensures positive outputs by both firms 2 and 3.

The price paid by firm 1 is $w^* = \frac{1+c}{3}$. The equilibrium profit of firm 1 is

$$\pi_1^* = \frac{(1-w^*)^2}{4} = \frac{(2-c)^2}{36}. \tag{21}$$

Welfare of country 1 is

$$W_1 = \frac{(2-c)^2}{36} + \frac{(2-c)^2}{72} = \frac{3(2-c)^2}{72}. \tag{22}$$

Now consider the case where firm 4 enters the market. In this situation, the inverse derived demand curve for firms 2 and 3 is given by (10), which is $w = \frac{2-d-3q_I}{2}$.

Firms 2 and 3 produce their outputs to maximize the following expressions respectively:

$$\underset{q_{I2}}{Max}(\frac{2-d-3q_{I2}-3q_{I3}}{2})q_{I2} \tag{23}$$

$$\underset{q_{I3}}{Max}(\frac{2-d-3q_{I2}-3q_{I3}}{2}-c)q_{I3}. \tag{24}$$

The equilibrium outputs of firms 2 and 3 are

$$q_{I2}^* = \frac{2-d+2c}{9} \quad \text{and} \quad q_{I3}^* = \frac{2-d-4c}{9}. \tag{25}$$

The second order conditions for maximization are satisfied. We assume that $d < 2-4c$, which ensures positive output by both firms 2 and 3.

The price paid by firms 1 and 4 is $w^* = \frac{2-d+2c}{6}$. The equilibrium outputs of firms 1 and 4 are

$$q_1^* = \frac{1-w^*+d}{3} = \frac{4+7d-2c}{18} \quad \text{and} \quad q_4^* = \frac{1-w^*-2d}{3} = \frac{4-11d-2c}{18}. \tag{26}$$

We assume that

$$d < \frac{4-2c}{11}, \tag{27}$$

which ensures that, upon entry, the outputs of both firms 1 and 4 are positive. Note that condition (14) is stricter than condition (27) if $c < \frac{3}{7}$. That is, upon entry, the

output of firm 4 is more likely to be positive under no patent protection in country 2 if the marginal cost of firm 3 (which is the entrant in country 2) is sufficiently small (i.e., $c < \frac{3}{7}$).

The net equilibrium profits of firms 1 and 4 are respectively

$$\pi_1^* = \frac{(4+7d-2c)^2}{324} \quad \text{and} \quad \pi_4^* = \frac{(4-11d-2c)^2}{324} - E\,. \tag{28}$$

It is immediate from (28) that, if there is patent protection in country 2, entry occurs in county 1 if

$$\pi_4^* > 0 \Rightarrow \frac{(4-11d-2c)^2}{324} > E\,. \tag{29}$$

Under entry of firm 4, welfare of country 1 is

$$W_1 = \frac{(4+7d-2c)^2 + (4-11d-2c)^2 + 2(4-2d-2c)^2}{324} - E\,, \tag{30a}$$

if firm 4 is from country 1, and it is

$$W_1 = \frac{(4+7d-2c)^2 + 2(4-2d-2c)^2}{324}, \tag{30b}$$

if firm 4 is not from country 1.

Proposition 1: *The incentive for entry in country 1 is higher under no patent protection in country 2 compared to patent protection in country 2.*

Proof: The gross profit of firm 4 is higher under no patent protection in country 2 than under patent protection in country 2, i.e., $\frac{(4-11d-2c)^2}{324} > \frac{(2-7d)^2}{144}$, if $d < 2-4c$, which is satisfied due to requirement for the positive output by firm 3 in (25). Q.E.D.

No patent protection in country 2 induces firm 3 to enter the market, thus reducing the price paid by the firms in country 1 and increasing the gross profits of firms 1 and 4. Thus, no patent protection in country 2 (compared to patent protection in country 2) makes entry by firm 4 more profitable.

Let us now consider the implications of patent protection in country 2 on welfare of country 1. It is immediate from (7) and (22a) and (22b), which are relevant for $\frac{(4-11d-2c)^2}{324} < E$, and from (17) and (30a) and (30b), which are relevant for $E < \frac{(2-7d)^2}{144}$, that if patent protection in country 2 does not affect the final goods market structure, welfare of country 1 is higher under no patent protection in country 2 than under patent protection in country 2. The reason for this result is easy to understand. If patent protection neither affects a firm's incentive for innovation (which happens in our analysis) nor affects the final goods market structure, no patent protection increases welfare by reducing the price paid by the final goods producers, thus reducing the deadweight loss. However, we will show below that even if patent protection does not affect the incentive for innovation, it is welfare improving if it affects the final goods market structure, and this happens whether or not firm 4 is from country 1.

It may worth noting that, if the patent protection in country 2 does not affect the final goods market structure, firm 1 earns higher profit under no patent protection (compared to patent protection) in country 2. This can be found by comparing (6) and (21), and (15) and (28). This result implies that in the presence of vertical technology transfer no patent protection in country 2 increasers firm 1's incentive for inventing a technology by raising its gross profit compared to the situation with patent protection in country 2. However, a crucial assumption behind this result is that patent protection

in country 2 does not affect the market structure. We show below that the result may change if patent protection affects the market structure.

Now, consider the situation where $E \in (\frac{(2-7d)^2}{144}, \frac{(4-11d-2c)^2}{324})$, i.e., firm 4 enters only if there is no patent protection in country 2. In this situation, (7) and (30a) are the relevant welfare expressions to compare *if firm 4 is from country 1*. The comparison of (7) and (30a) shows that welfare of country 1 is higher under patent protection in country 2 compared to no patent protection in country 2 if

$$E > \frac{(4+7d-2c)^2 + (4-11d-2c)^2 + 2(4-2d-2c)^2}{324} - \frac{3}{32}. \qquad (31)$$

Since left hand side (LHS) of (31) is increasing in E, welfare of country 1 can be higher under patent protection in country 2 compared to no patent protection in country 2 provided condition (31) is satisfied at least for $E = \frac{(4-11d-2c)^2}{324}$. If $E = \frac{(4-11d-2c)^2}{324}$, condition (31) reduces to

$$243 - 8(4+7d-2c)^2 - 16(4-2d-2c)^2 > 0. \qquad (32)$$

If $d = c$, condition (32) does not hold in the relevant range of c, which is $c < \frac{2}{7}$, where the outputs of the firms are positive.

Note that LHS of (32) is increasing in c over $[0, \frac{1}{2}]$. We get that if $c = 0$, (32) is not satisfied for the feasible values of d, which lies between 0 and $\frac{2}{7}$.[3] Hence, welfare of country 1 is higher under no patent protection in country 2 compared to patent protection in country 2 if c is at its minimum value 0.

Now, consider the case where $c \to \frac{1}{2}$. In this situation, the relevant value of $d \to 0$. This is because, if $c \to \frac{1}{2}$, entry occurs in country 1 if $d \to 0$. We get that (32) holds for $c \to \frac{1}{2}$ and $d \to 0$. As c falls from $\frac{1}{2}$, the relevant value of d increases from 0, and (32) holds provided c is not very small. In general, $243 - 8(4 + 7d - 2c)^2 - 16(4 - 2d - 2c)^2 = 0$ can have a positive real root $d = \frac{-16 + 8c + 3\sqrt{2}\sqrt{-85 + 256c - 64c^2}}{76}$ provided c is not very small. Hence, patent protection (compared to no patent protection) in country 2 increases welfare of country 1 if c is sufficiently high and d is sufficiently small.

It is worth mentioning that if we evaluate condition (31) at $E = \frac{(2-7d)^2}{144}$, and consider $d = 0$ and $0 \le c < \frac{1}{2}$, welfare of country 1 is higher under patent protection in country 2 compared to no patent protection in country 2 if c is sufficiently high. However, (31) does not hold at $E = \frac{(2-7d)^2}{144}$ if either $d = c$ or $c = 0$ and $0 \le d < \frac{2}{7}$. Hence, patent protection (compared to no patent protection) in country 2 increases welfare of country 1 if patent protection in country 2 deters entry of firm 4, c is sufficiently high and d is sufficiently small.

The above discussion gives the following proposition immediately.

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[3] If $c = 0$, the relevant values of d, which ensure positive outputs, are given by $0 \le d < \frac{2}{7}$.

Proposition 2: *Assume that the potential entrant in the final goods market is from country 1. Patent protection in country 2 increases welfare of country 1 compared to no patent protection in country 2 if (i) patent protection deters entry in the final goods market, (ii) the marginal cost difference between the incumbent and the entrant final goods producers (which is given by d) is sufficiently small, and (iii) the marginal cost difference between the incumbent and the entrant in country 2 (which is given by c) is sufficiently high.*

If c is very high, no patent protection in country 2 does not significantly reducing the price paid by the final goods producers compared to no patent protection in country 2. Further, if patent protection deters entry when d is very small, it implies that the cost of entry is significantly high, thus imposing significant cost on country 1. As a result, the higher entry cost outweighs the extra gain from competition, thus reducing welfare of country 1 under no patent protection in country 2 compared to patent protection in country 2.

It is worth noting that the effect of patent protection in country 2 has an ambiguous effect on the profit of firm 1. It follows from (6) and (28) that the profit of firm 1 is higher under "patent protection in country 2 with no entry by firm 4" compared to "no patent in country 2 with entry of firm 4" if $\frac{1+4c}{14} > d$. We also get that the parameter values where patent protection in country 2 increases welfare of country 1 provide higher profit of firm 1 under patent protection in country 2 compared to no patent protection in country 2.

It is now easy to see how patent protection (compared to no patent protection) in country 2 affects welfare of country 1 if *firm 4 is not from country 1* and

$E \in (\frac{(2-7d)^2}{144}, \frac{(4-11d-2c)^2}{324})$. If firm 4 is not from country 1, the net profit of firm 4 does not appear in the welfare calculation of country 1, and (7) and (30b) are relevant welfare expressions for country 1. However, it must be noted that this situation is similar to the previous case where firm 4 is from country 1 but $E = \frac{(4-11d-2c)^2}{324}$, so that the net profit of firm 4 does not affect welfare of country 1. In this situation, welfare of country 1 is higher under patent protection in country 2 than no patent protection in country 2 if

$$243 > 8(4+7d-2c)^2 + 16(4-2d-2c)^2. \quad (33)$$

As shown above, condition (33) is not satisfied for c = 0, while it is satisfied for $c \to \frac{1}{2}$ and $d \to 0$. In general, $243 - 8(4+7d-2c)^2 - 16(4-2d-2c)^2 = 0$ has a positive real root $d = \frac{-16+8c+3\sqrt{2}\sqrt{-85+256c-64c^2}}{76}$ if c is not very small. Hence, if firm 4 is not from country 1, patent protection in country 2 increases welfare of country 1 compared to no patent protection in country 2 if the conditions similar to Proposition 2 is satisfied, i.e., patent protection in country 2 deters entry in the final goods market, c is sufficiently high and d is sufficiently small.

If firm 4 is not from country 1, the profit of firm 4 does not affect welfare of country 1. However, entry of firm 4 under no patent protection reduces firm 1's profit compared to patent protection in country 2. Further, firm 1's loss of profit following entry of firm 4 increases as *d* reduces. On the other hand, entry in country 2 under no patent protection helps the final goods producers by reducing the price paid by them. However, if *c* is very high, the benefit of entry in country 2 due to the lower price paid by the final goods producers is not significant. Hence, if *c* is very high and *d* is

very small, patent protection (compared to no patent protection) increases welfare of country 1 by deterring entry in the final goods market.

3. Conclusion

There is a vast literature examining the rationale for extending patent protection in developing countries. However, that literature did not pay much attention to the vertical relationship between developed and developing country firms, while empirical evidences indicate that vertical technology transfer is quire pervasive.

We analyze how patent protection in a developing country affects welfare of the developed country through its impact on market structure. We show that patent protection in the developing country increase welfare of the developed country only if it prevents entry in the final goods market. The marginal cost differences between the incumbent and the entrant final goods producers and between the incumbent and the entrant producers in the developing country also play important role in improving developed-country welfare following patent protection in the developing country.

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